IDENTIFICATION OF THE POLLUTION POTENTIAL OF THE HARVESTING AND PREUTILIZATION PROCESSING OF PEAT AS AN ENERGY COMMODITY

FINAL REPORT

submitted to

ENVIRONMENT CANADA

by
WASHBURN & GILLIS ASSOCIATES LTD.
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Mr. M. P. Guilcher
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Dear Mr. Guilcher:

We are pleased to submit our report "Identification of the Pollution Potential of the Harvesting and Preutilization Processing of Peat as an Energy Commodity".

In this report we have compiled information on fuel peat harvesting techniques and processes. Pollution control procedures are reviewed and assessed. Particular areas where more research is required are identified.

We have prepared abstracts from the particularly relevant references used. These abstracts are presented in an appendix. Our sources have included published information as well as direct discussions with researchers..

We trust that this report meets your requirements and will be pleased to discuss it at your convenience.

Yours very truly,

Owen V. Washburn
President

lmm
Enclosure

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ABSTRACT

The literature was reviewed to identify sources of environmental impacts resulting from the mining and pre-utilization of fuel peat in Canada and to identify possible methods to mitigate these impacts. Much of the information available from the literature applies to non-fuel uses of peat and is presented in a general manner because details are site specific.

Dry mining of peat may result in increased levels of particulates and increased acidity. Particulate levels may be reduced through the use of settling ponds and through the design of drainage ditches so runoff will filter through peat before entering receiving waters. Increased acidity of drainage water may be reduced by treating wastewater in a manner similar to acid drainage from coal mines. Impacts of hydraulic mining of peat differ from those of dry mining techniques and are dependant on the method of dewatering. Wet carbonization and partial wet oxidation are methods proposed to break down the collodial structure of peat to facilitate mechanical dewatering. The wastewater treatment techniques recommended are a combination of anaerobic and aerobic treatments which aim to lower BOD, COD and remove organics. Information on waste streams from wet carbonization and partial wet oxidation is based on laboratory studies and pilot tests rather than full scale production operations.

RESUME

La documentation a été étudiée en vue d'identifier les causes des effets environnementaux résultant de l'extraction minière et de la pré-utilisation de la tourbe combustible au Canada et en vue d'identifier des méthodes pouvant atténuer ces effets. Une bonne partie de l'information contenue dans la documentation s'applique aux utilisations non combustibles de la tourbe et est présentée sous forme générale car les détails ont trait aux caractéristiques du lieu.

L'extraction minière à sec de la tourbe peut accroître les niveaux de particules et donner lieu à une acidité accrue. Les niveaux de particules peuvent être diminués en utilisant des étangs de décantation et en construisant les fossés de drainage de façon que les écoulements puissent être filtrés par la tourbe avant de pénétrer dans les eaux réceptrices. L'acidité accrue des eaux de drainage peut être prévenue en traitant les eaux d'égout selon une méthode semblable à celle du drainage de l'acide dans les mines de charbon. Les effets de l'extraction minière hydraulique de la tourbe sont différents de ceux des techniques d'extraction à sec et dépendent de la méthode d'assèchement. La carbonisation en milieu liquide et l'oxydation partielle en milieu liquide sont des méthodes proposées pour séparer la structure colloïdale de la tourbe afin de faciliter l'assèchement mécanique. Les techniques de traitement des eaux d'égout recommandées sont une combinaison des traitements aérobies et anaérobies qui visent à réduire le dbo et le dco et à supprimer les matières organiques. Les renseignements concernant les effluents de déchets provenant de la carbonisation en milieu liquide et de l'oxydation partielle en milieu liquide sont fondés sur des études de laboratoire et des essais pilotes plutôt que sur des opérations industrielles.

1.0 INTRODUCTION

The Parliamentary Committee on Energy Alternatives has identified peat as a possible future alternative to conventional fuels (House of Commons, 1981). Although the peat resource has not been completely inventoried, estimates based on air photo analyses indicate that Canada has large reserves of peat (Tibbetts and Ismail, 1980). Because it falls within the mandate of Environment Canada to ensure that the development of peat as an alternative fuel proceeds with minimal impact to the environment, information relating to the pollution potential of peat harvesting and utilization is being assembled and assessed so that environmental protection criteria specific to the Canadian peat resource can be established. As the initial phase in the effort, a literature survey and assessment of potential pollution problems associated with the use of peat deposits was prepared (Washburn & Gillis Associates Ltd., 1982). This assessment was based upon recorded analyses of peat solids and liquids with respect to trace metals, organic compounds, volatile matter, carbon content, pH, etc.

In the second phase of this work, literature sources used in the first phase were reviewed to identify existing and proposed methods which could be used to mitigate impacts occurring during the extraction of peat and prior to its use as a fuel. This report contains a description of these methods and an assessment of their utility in the context of the Canadian peat resource.

Specifically, the goals of this second phase were to:

i) conduct a literature review and identify existing technology applicable to air pollution control and wastewater treatment associated with peat extraction and pre-utilization processes;

ii) list the relevant references;

iii) provide an interpretation of available information as it applies to the Canadian peat resource;

iv) identify areas in which more data and technology information is needed to provide a more comprehensive assessment of the environmental implications of utilizing this resource as an energy commodity; and

v) recommend research thrusts which might provide the needed information.

Information was obtained from a computerized literature search, Chemistry Abstracts, Peat Abstracts and from discussions with researchers and resource managers. In assembling the information base attempts were made to include the most current data. However, due to the increased interest in Canada's peat resource, an intensive research effort is now underway to more fully assess the peat resource and the potential for utilization. Much of this information will be availbale in the near future.

For example, The National Research Council of Canada is engaged in a number of literature and bench scale research projects which may ultimately add significantly to the information base regarding existing and innovative harvesting and preutilization processes and the physical/chemical nature of any waste products resulting from these processes. As data from this and similar efforts become available, information in this report will require updating.

2.0 SITE PREPARATION AND MINING

Peatlands are most commonly classified as bogs or fens. The bog (common to the Atlantic Provinces and eastern Quebec) receives water through precipitation and there is little underground movement of water. The fen, on the other hand, is influenced by groundwater. This type of peatland is common to central Canada.

Peat may be mined using either a dry method or a wet method. The basic difference between the methods is when during the mining process, the majority of the water is removed from the peat. Dry mining involves draining the peatland and the use of solar radiation to dry the peat. Wet mining involves excavating the peat without first draining the peatland; the moisture content of the peat is then lowered at some further point in processing.

The environmental impacts associated with site preparation for both wet and dry methods and the impacts of the actual mining are not well documented nor well understood. Such impacts have been a concern in the United States during the last 10 years when peat has been considered for energy use (D. Keys, N.B. Dept. of Natural Resources, personal communication to C. Kent, 1983). In Finland, in the last five to ten years, peat has become more important as an energy commodity. As a result, the State-owned Fuel Centre in Finland (VAPO) has conducted extensive monitoring on peat drainage (which amounts to approximately 1% of forested land that is drained), and no major environmental problems are forseen (Sheppard, National Research Council, personal communication to C. Kent, 1983).

The sections that follow are an account of the procedures used in preparing peatland for mining, dry and wet mining techniques, possible impacts associated with these procedures, and methods to mitigate these impacts.

This investigation found that most of the mitigative methods described in the literature have not been used at the production level in those areas of the world in which peat is used as a source of energy. This is likely due to disagreement as to the actual impact of mining peat; research to date has not shown conclusively that certain of the suspected impacts do occur. Most of the peat literature from Canada and the United States pertains to peatlands that are being mined for horticultural peat. Due to the nature of the more humified (decomposed) fuel peat, only a portion of this literature is applicable to energy peat.

2.1 Site Preparation

Draining the peatland (when using the dry method and the wet method to some extent) and removal of vegetative cover are the main activities in preparing a peatland for production. Draining involves the excavation of perimeter ditches and production field ditches to lower the water table and to collect bog drainage and runoff - especially during periods of peak flow (Monenco Ontario Ltd., 1981, and Paivanen and Wells, 1977). Draining is also necessary to enable the use of heavy production machinery. The clearing of vegetation entails removing the vegetation overlying the horticultural and/or fuel peat. A brief description of these processes, their impacts on the environment, and possible methods to mitigate these impacts is provided in the following sections.

2.1.1 Draining

Draining a peatland can affect quality and quantity of peatland water and runoff. Clausen and Brooks (1980) and Clausen et al. (1980) reported a seasonal variation in water quality parameters for peatlands and found a difference between drainage waters of bogs and fens. Levels of dissolved oxygen, pH, potassium, conductivity, acidity, calcium, magnesium, iron, aluminum, and sulfate all varied seasonally, thus the impact on receiving waters would vary accordingly. Bog drainage waters had more humic and fulvic acids (humates) and less plant nutrients than fens. When a fen is drained there could be a decrease in calcium and bicarbonate concentrations and an increase in nitrates in waters draining from the fen. Draining a bog would increase calcium and bicarbonate concentrations and decrease nitrates. (Clausen and Brooks, 1980). Measurements taken immediately below a point where drainage waters from a bog actively mined for fuel peat in Newfoundland entered a stream showed a decrease in pH, alkalinity, specific conductance, hardness, calcium and magnesium and an increase in nitrate, turbidity, suspended solids, total organic carbon and barium relative to measurements taken upstream of the drainage input. Values approached normal in samples taken 1.3 km downstream (Osborne, personal communication to G. Gillis, 1982). In a study of four peatlands in Minnesota, Clausen et al. (1981) found a greater fluctuation in acidity and lower oxygen concentrations in waters draining from disturbed peatlands than was the case with undisturbed peatlands. Accumulated cations and acidic material could be released downstream (Reed et al., 1981), which could produce chemical differences between the discharges and the receiving waters. This could lead to a change in downstream vegetation and could in turn affect wildlife (Minnesota Department of Natural Resources, 1981).

There appears also to be changes in chemistry of peatland waters with time. Generally, draining peatlands can result in a gradual increase with time of drainage (2 to 15 years) in pH, as well as the concentration of magnesium, sulfates, and humates in water draining from the peatland, Largin (1976).

There are conflicting reports on the impact of peatland water release on receiving waters. The ultimate use of the receiving waters is important. If the receiving waters run into a drinking water supply, the compounds in the water should be examined to determine the levels of potential contaminants and their possible effects. For example, fulvic acids, when chlorinated, have been shown to be precursors to dihaloacetonitriles, which have been shown to act as mutagens in bacterial assays (Oliver, 1983). Crawford (1978) found, through laboratory experiments, that the release of humates into streams or lakes could have adverse effects on fish, but these toxic effects would require a large infusion of bog water. In another experiment, Crawford (ibid) found that a lake receiving bog water of pH 5.5 could buffer an equal volume of this water. This, of course, is dependant on the chemical state of the lake, ie., it's buffering capacity. Humates can chelate inorganic ions found in peatland waters forming weak field chelation complexes. The ions may thus become less available to vegetation in and adjacent to the receiving water because of the size and shape of these organic complexes (Spear and Pierce, 1979). There could be a reduction in light penetration and therefore a reduction in primary production[1] because of increases in water colour due

[1] Primary production is the accumulation of the sun's energy in the form of organic substances by green plants. (Smith, 1977)

to the increased levels of humates. Diluted bog waters however, could also have a beneficial effect on the biota in a receiving stream as they may provide some additional nutrients fostering an increase in primary production (Crawford, 1978).

When runoff from peatlands flows through areas containing mineral soils, the acidity of the runoff may be buffered (Clausen et al., 1981). Measurements taken 7.4 km downstream of a transitional peatland[1] site show an increase in pH, (as well as dissolved oxygen content and specific conductivity) as compared to those values from samples collected where peatland drainage waters run into the stream. These changes occurred because of dilution and mixing of the drainage waters with runoff from mineral soils (Clausen et al., ibid.). In areas with low buffering capacity where acid precipitation is a problem[2], there could be a severe effect on the pH of receiving waters from peat drainage water (Minnesota Department of Natural Resources, 1981, and Monenco Ontario Ltd., 1981).

Changes in pH are important because they affect the dissociation of weak acids and bases and the solubility of some metal compounds (Katz et al., 1979). Both these effects may alter the toxicity of compounds

1 A transitional peatland has some characteristics of both a bog and a fen.

2 Acid precipitation may not be a problem in areas where calcareous bedrock predominates. In areas containing granitic and other acidic igneous or metamorphic bedrock there is little natural buffering capacity, thus if the precipitation has a low pH, the impacts are greater. For more information on acid precipitation see Harvey, 1976 and Schofield, 1976.

found in the receiving water. For example, increases in heavy metal concentrations have the potential to cause severe effects on aquatic biota. Although many reports indicate the presence of elevated levels of heavy metals in peat, little difference has been reported between the levels of these metals in runoff from disturbed and virgin peatlands (Minnesota Department of Natural Resources, 1981). Mathur (personal communication to G. Gillis, 1982) expressed concern about secondary release of metals downstream of mining activities. As mentioned previously, these metals readily form chelation complexes with humic acids at low pH. Downstream, as pH increases, these weak field bonds may break, releasing the metals.

Some metals (e.g. Na, Ca, Al, Mn) which may form chelation complexes with humic acids (at a low pH), may be released as pH increases (Benes et al., 1976). In the natural system an increase in pH would likely occur downstream due to the natural buffering capacity of the receiving water and the metals would be released in solution. If the pH is sufficiently high metals may precipitate from solution (e.g. Cu, Zn, Pb, Ni and Mn are precipitated in the pH range 8 to 11 (Environment Canada, 1977)).

Although there has been no observed or recorded evidence of saltwater intrusion into freshwater aquifiers in coastal areas where drainage occurs below sea level, Reed et al., (1981) has hypothesized that this could be a problem. Coastal bogs are found in the Atlantic Provinces (e.g., Labrador, Nfld, Yarmouth, N.S., Northern New Brunswick),

but these are for the most part at least five miles from the coast and would not likely have the problem of saltwater intrusion (H. Hirvonen, Environment Canada, personal communication to C. Kent, 1983).

Hydrological regimes are very important to the ecological balance of the peatland, but effects of disturbance on these regimes are not yet well documented nor understood. Draining, which lowers the bog water table and increases subsurface flow (Reed et al., ibid.), may result in a temporary increase in capability of the peatland to buffer peak flows, but an overall increase in the amount of water released (Brooks and Predmore, 1978). Elsewhere it has been suggested that peak flows would occur sooner after a rainfall (Minnesota Department of Natural Resources, 1981).

When fens are drained, effects on groundwater must be considered. There is some disagreement about such impacts since there is no documentation in the literature based on field measurements of groundwater effects due to peat mining. However, there is evidence which has been used to infer effects of groundwater on the basis of surficial discharge and recharge characteristics. Clausen (1979) gives an account of a large fen in Northern Minnesota (approximately 50 x 100 miles) that was ditched in the 1920's to create farmland. The attempt was unsuccessful because the drainage ditches were too widely spaced (one mile intervals), (Clausen, 1983, personal communication to C. Kent). Based on aerial photography, there is evidence that the ditching interrupted groundwater in the fen for a

distance of about 50 miles. Significant changes in the downstream vegetation to a drier state were observed, ie. more brush, less moss (Clausen, ibid.). It should be noted that these effects are site specific, for example, in Europe, only local impacts of draining were reported with no effect evident 50m from draining sites (Monenco Ontario Ltd., 1981).

2.1.2 Clearing Vegetation

In the Atlantic Region the typical bog, which would be used for fuel peat is not treed. These bogs have sphagnum mosses plus small shrubs; huckleberry is common in the southern areas and bake apple becomes more prominent in more northern areas such as in Labrador. When a bog is put into production, these shrubs are burned either on the site or carried away (H. Hirvonen, personal communication to C. Kent, 1983). In Ontario and western Canada, black spruce bogs are common. On treed bogs in Minnesota (these are horticulture peat bogs) logging operations are carried out in the winter and the bog is drained once the area thaws. (H. Hirvonen, ibid).

Besides the obvious physical alteration, removal of vegetation changes the biological habitat. The immediate impact would be the loss to the area of certain species of plants and wildlife. Peatlands offer unique habitat, which some species such as the bog lemming utilize year-round. For other animals, such as the deer, snowshoe hare, and some bird species, peatlands are an important area at certain times of the year (Minnesota Department of Natural Resources, 1981). Plants receiving natural drainage from peatlands act as nutrient traps removing nutrients such as nitrogen and

phosphorous. Clearing these plants could increase the release of the nutrients (Lofton, 1980), thereby changing the productivity of downstream areas. Initially, there could be an increase in all productivity, especially phytoplankton and algae. As these plants decay there exists the potential for an oxygen deficiency (as a result of high biochemical oxygen demand) which may cause a dramatic decrease in numbers of all organisms.

In a fen, where there are open water areas, aquatic plants act as baffles reducing wave action and their removal could result in an increase in turbidity (Lofton, ibid.). Fish will avoid areas of excessive turbidity (Hynes, 1970) and primary production could also be reduced because of decreased light penetration. Removal of vegetation also may result in erosion, which leads to increased particulate loading in the receiving waters. In Finland, after a 3 cm rainfall, 100 kg/ha and 1000 mg/L of solid matter were measured in peat drainage waters. The resulting runoff could have an oxygen consumption of greater than 100 mg O_2/L (Suoninen, 1982).

The hydrological budget can also be altered as a result of clearing vegetation. Removal of vegetation lowers the water table. As a result, evapotranspiration is decreased, and annual runoff is increased somewhat because there is no interception or transpiration by plants and less infiltration (Reed et al., 1981).

Most Canadian peatlands that would be harvested for fuel (greater than one metre thick) are relatively unproductive biologically, compared to other wetlands and forested land, (Monenco Ontario Ltd., 1981). The most

productive areas of these peatlands are the perimeters which contain a more diverse biological community. The perimeter of a peatland is not harvested because it is generally less than one metre thick (Monenco Ontario, ibid). The authors suggest that draining a peatland would allow more varied vegetation on the perimeter, resulting in habitats that could be more suitable for wildlife (Monenco Ontario, ibid).

2.2 Mining

There are basically two methods used to mine peat - dry and wet. When dry mining techniques are used, the peatland is drained and the peat is extracted and left to dry on the site. Wet mining techniques, including slurry ditch, hydro-peat, and slurry peat methods, have been used infrequently (Aspinal and Hudak, 1980). An experimental hydraulic mining technique is currently being developed (W. Mankinen, Montreal Engineering Co. Ltd., personal communication to G. Gillis, 1983) based on existing Soviet technology. Such wet mining and transport of peat slurry off the bog depends on addition of water to the bog first to make the peat accessible and second to slurry the peat for transport[1].

The environmental effects of wet mining are similar to those of the dry mining techniques with respect to surface disruption. The major difference is that water is added to the peat during wet mining and slurry

[1] More information on this technique will be available when the National Research Council receives the final reports from Montreal Engineering Co. Ltd.

transportation, which increases volume of wastewater following dewatering. In existing operations (in the USSR, Finland and British Columbia), this water is returned to the bog as it is considered to be basically a diluted bog water, although there may be an increase in the concentration of heavy metals which are removed from the peat during dewatering. Hydraulic impacts may be anticipated if the water table of the bog is increased above the previous level.

The two basic methods of dry mining peat are milling the peat and removing the peat in sods. When peat is mined using the milled method, the first few centimetres of peat are cut from the surface of the peatland and left to dry. This material is turned over up to about five times (depending on the weather) to facilitate drying to a moisture content of 45 - 50% by weight (Monenco Ontario Ltd., 1981). The milled peat can then be collected by either plowing into piles on the peat site (ridging), or by vacuuming. The approximate size of milled peat ranges from 0.1 to 1.0 cm and is dependant on the type of milling (ridge or vacuum) and quality control on the site.

Sod peat mining entails cutting peat in sods, removing it from the bog and leaving it to dry until 75% moisture content is reached. The sods, which range in size from 10 to 12 cm wide by 30 to 35 cm long, are then stacked in windrows and left to further air dry to achieve 35% moisture content (Monenco Ontario Ltd., ibid.). A problem with either dry technique is the dependance on solar drying which may limit the harvest season. Canada's climate allows for an average of about three to four months of good harvesting weather.

A problem associated with either milling or sod peat mining is flooding of the surrounding area. As the peat is removed the capacity of the area to store water is reduced (Reed et al., 1981).

The impact of sod peat mining on air quality and water quality is generally isolated to the immediate area, but milled peat can affect a larger area. This is because milled peat is smaller in size than sod peat. The solid peat particles produced by milling peat may be carried by wind or runoff (Ertugrul and Sober, 1979). Peat dust is a major by-product of the milled peat method. If biota in the area were coated with this dust (levels of dust were not quoted), basic processes such as respiration could be adversely affected (Ertugrul and Solar, ibid). Riihimaki,et al, 1980 found that workers exposed to peat dust at a mining site complained of irritations of skin, eyes, nose, and throat, and respiratory problems. Average dust concentrations were highest during milling and ridging (24.6 mg/m^3) and during the moving of the ridge (33.9 mg/m^3). The effects of peat dust in the area beyond the mining site are not known and research is needed to determine the levels of peat dust which could be harmful to nearby communities. Fallout areas of peat dust should be investigated relative to moisture content - wind directions and velocities, temperature, humidity, topography and nature of natural ground cover.

The fines produced by the milled method can also be carried in various quantities via drainage ditches into receiving waters. High levels of fines could have dramatic effects on the aquatic biota in receiving

waters. Such material may fill the interstices in gravel spawning areas and render such areas unsuitable for the incubation of fish eggs or it may cause abrasive injury to fish gills (Clausen and Brooks, 1980). It is likely that fish would move out of the area before such injury could occur (Hynes, 1970), however, the capacity of the affected area to produce fish could be lost if preventative measures were not taken. The increase in fines could also decrease primary production through a reduction in depth of light penetration in the water column or should attached macrophytes become coated with this material. Organic overloading (extreme biochemical oxygen demand) could also be a problem with increased silting, especially in late summer and early fall when water levels are low, and also under ice in winter when oxygen exchange is reduced (Clausen et al , 1981).

As peat is mined, more of the underlying peat is exposed. In this situation ammonium (NH_4^+) present in the peat is oxidized yielding nitrate (NO_3^-). Reed et al., (1981), suggested there could be eutrophication of receiving water due to increased amounts of nitrate in the drainage water. Osborne (personal communication to G. Gillis, 1982), found nitrate to increase in samples taken immediately downstream of the outlet of a mined bog, but values approached background levels in samples taken 1.3 km downstream.

2.3 Mitigation of Impacts

Mitigative measures for wet and dry methods are similar apart from volume of water involved with mining techniques. Little information is

available pertaining to the mitigation of impacts resulting from mining and site preparation and much of it is very general. This is probably because the nature and extent of impacts and mitigating measures which might counteract the impacts tend to be very site-specific (Hazen and Beeson, 1979) and little site-specific work has been done. In Finland, however, there has been an extensive monitoring program from which it was concluded that there is a minimal chemical impact on receiving waters and settling ponds to remove particulate matter are the only mitigative measure required (Sheppard, personal communication to C. Kent, 1983).

Ideally, as many impacts as possible are avoided by good planning. For example, by having a set of criteria on which to base the selection of peatlands to be developed, losses of unique features, habitat, and forest resources can be avoided. By developing a mine plan and having a policy to limit the size of peatlands leased for development, the extent of hydrological and vegetative impacts can be lessened (Minnesota Department of Natural Resources, 1981).

The Minnesota Department of Natural Resources has developed policy recommendations for the development of peatlands (Minnesota Department of Natural Resources, ibid., and Clausen et al., 1981) The Environmental Protection Service of Environment Canada, Newfoundland District, have also established guidelines for peatland development (McCubbin, undated). Because peatlands vary, these guidelines are general and their implementation would have to be tailored for each development.

Existing features of the bog should be used to limit the impact of drainage waters. It is recommended that a holding pond be used to settle out particles and that a buffer area be left between the drainage ditches and receiving waters, to filter out nutrients, organics and other solids (Minnesota Department of Natural Resources, 1981; and Hazen and Beeson, 1979). Plants in the buffer area could then utilize the nutrients and trap the heavy metals that otherwise might be released downstream (Hazen and Beeson, ibid.).

Suoninen (1982) suggests that settling ponds should have an area of 10 m^2 for each ha of peatland under production. A settling pond could be a natural open water area, or could be man-made, but in either case, it should be close to where drainage exits the peatland (Hazen and Beeson, ibid.). A system of baffle plates in a drainage ditch in series with a holding pond and a filtration dam has been suggested by Buggie (1981) to be an economical way to reduce the discharge of solids to receiving waters. The findings of Buggie's study (conducted on a New Brunswick peatland with 128 ha under production) were not implemented because it was ultimately decided that the recommended wastewater treatment methods were not required because impacts were not seen to outweigh the costs of implementing such procedures (Keys, personal communication to C. Kent, 1983). A pond already located on the site was to be used as a settling pond. It had an area of 28,100 m^2 and depth of 1.5 m. A filtration dam (of gravel and limestone) 12 m long was to be located on the outlet of the holding pond. One baffle plate was to be placed at the end of each field drainage ditch and three upstream of the inlet flume to the holding pond. Denser particles were

expected to settle on the baffle plates with most of the remaining particles settling in the holding pond. The remaining fines were to be filtered out by the filtration dam.

In northern New Brunswick some peatlands under production for horticulture peat are located along the coast. In one of these mining areas which is located immediately next to the coast, pumphouses are located at the end of the drainage ditches to prevent flooding by seawater (Keys, personal communication to C. Kent, 1983). Peat is located in the upper aquifer zone and there is likely little chance of upconing of saltwater through the stratified sandstone, shale sequences (A. Gregory, New Brunswick Department of Environment, personal communication to C. Kent, 1983). However, it should be noted that it is difficult to predict with certainty the impact of mine operations in peatland located on the coast because to date little is known about the hydrogeology of peatlands and their role as aquifer recharge areas or groundwater storage areas. Impacts would also depend upon the location of the peatland in relation to other uses.

Control of acidity of drainage water may be necessary where peatlands are disturbed. According to Ertugrul and Sober (1980) this can be achieved by chemical neutralizing or mechanically aerating holding ponds. Acidity could also be controlled by mixing the drainage water with upwellings from near surface aquifers or by passing it through calcareous in situ soils (Ertugrul and Sober, ibid., and Hazen and Beeson, 1979). Buggie (1981) suggests that crushed limestone be put on the downstream side of the filtration dam (see above).

A similar problem with acidic wastewaters is encountered in the coal industry. The acidity produced in the wastewater of coal mines results from the oxidation of pyrite (FeS_2), yielding ferrous iron and sulfate (Stumm and Morgan, 1981). Reagents such as hydrated lime ($Ca(OH)_2$), calcined lime (CaO), soda ash (Na_2Co_3) and caustic soda (NaOH) are used to neutralize the acid drainage water (Costle et al., 1981). Hydrated lime is the reagent most commonly used and it is added either in a slurry or in its dry form (Costle et al., ibid.) Calcined lime is used in the same manner, but at larger operations and soda ash is also used in this manner, but is more readily consumed and more dangerous to handle (Costle et al., ibid). Less caustic soda is needed (relative to the other reagents) and it reacts quickly, but it has a high freezing temperature, it is dangerous to handle and it requires close monitoring to prevent over treatment (Costle et al., ibid)).

Powdered lime in a slurry with mine water is presently used to alleviate the problem of acid water drainage from coal mines but there are associated problems (Kim et al., 1982). Lime is an alkaline material and may raise pH to an unnaturally high level. This can be controlled by varying lime addition rates manually or automatically (Costle et al., 1981). Also, the precipitate forms a flocculent sludge which is difficult and expensive to handle and may adversely affect the economics of using peat as a fuel. Limestone is being considered as an alternative (Kim et al., ibid.) with fine crushed limestone in a slurry with mine water added to the wastewater. A surface aerator would then be used to eliminate carbon

dioxide and oxidize ferrous iron produced. The resulting crystalline sludge of gypsum and hydrous iron oxide would precipitate in the settling pond and the pH of the drainage would be raised to about 7.0. However, the use of a surface aerator is expensive and cost appears to be the major drawback of the limestone method.

Another interesting treatment system (proposed for coal mine drainage) is to use a peat bog for part of the treatment process. This natural treatment system is being investigated by the Bureau of Mines, United States Dept. of the Interior (Kim et al., 1982). In an area where drainage flow is low, water would drain through an artificial sphagnum bog and then through a limestone bed located next to the bog. (The method of creating a bog was not described.) The moss in the bog would remove iron via precipitation and ion exchange, and the limestone would decrease the acidity of the wastewater. Similar effects were found when a portable bog, consisting of a limestone bed and live sphagnum moss was constructed next to a stream which received acid mine drainage (Peer Consultants and Brehm Laboratory, 1983). This system also raised pH, reduced acidity and removed iron from the drainage waters.

The method selected to treat peat drainage waters depends upon the ultimate use of the effluent stream. For example, if water from a peat operation contributes to a drinking water supply or a recreational area much more attention must be given to the quality and aesthetics of the effluent. In the U.S.S.R., outside Moscow, there is a problem with drainage waters of

natural and disturbed peatlands running into a drinking water supply (Kaminskiy and Orlov, 1979). Two methods are employed to reduce the colour of this water. The material is either flocculated and filtered out, or the coloured substances are oxidized. (No examples were given for the first method, but three were given for the second.). Ozonation is one way to oxidize these compounds and probably the most practical. A large ozonation plant with a 1,200,000 m^3/day output has been set up in the area. The optimum concentration of ozone to decolourize water was found to be 2-4 mg per litre and its ability to decolourize increased with pH. Ozonation also decreased iron and manganese in the water. Kaminskiy and Orlov (ibid.) reported two other procedures to reduce colour in the laboratory which involved the use of radiation and an accelerated electron beam. (The latter can reduce colour tenfold.) Radiation of 1×10^3 J/kg of bog water was found to reduce colour, decontaminate the water, and eliminate smell and aftertaste.

Guidelines for mining operations are established to minimize impacts. A factor to be considered in planning a mine is the direction and strength of the prevailing wind. Another is the topography of the site (Ertugrul and Sober, 1979). Conklin (1978) suggests wind barriers of trees, shrubs, snow fences or vine-covered chicken wire would protect the downwind side of the peat site for a distance of 10 to 15 times the barrier height, however there are no actual data on this technique being used in operating peat mines (Ertugrul and Sober, 1979). The loss of peat dust through wind erosion is not only an environmental problem, but also an economic one, so it is in the best interest of the operator to reduce such emissions.

When peatland is prepared for mining, the potential for fires in the area increases. In Finland, the Ministry of the Interior has set up regulations to lessen the hazard (Suoninen, 1982). The following requirements are covered: (1) the notification of fire authorities of progress during planning and bog preparation stages; (2) the establishment of a fire-fighting plan approved by local fire authorities; (3) the use of only properly designed and maintained equipment on the bog, i.e., equipment which is constructed to ensure that sparks cannot escape and which is cleaned every shift; (4) the familiarizing of all personnel with the location of fire equipment; (5) the training of certain personnel who will be responsible for fire equipment; (6) the establishment of wells, water intake basins of 10 m^3, and tanks on the site; (7) the intensification of dry season fire watches when winds are greater than 5 m/s, and (8) the stopping of hazardous work when winds exceed 10 m/s. Drainage ditch networks which also act as a fire barrier should be designed to permit reflooding in case of fire (Reed et al., 1981).

To prevent undesired flooding of the site, Suoninen (1982) suggested restricting water flows to the drainage area, by diversions, constructing embankments, clearing obstructions from channels and building reservoir basins and regulating dams. A holding pond (with overflow capacity for storm events) and a filtration dam could reduce peak flows into the outlet drainage (Buggie, 1981).

The movement of water both above and below the surface of the peatland could be lessened by installing impervious barriers. This could be achieved by using relatively impermeable materials such as hemic or sapric[1] peat, or clays on the bottom of holding ponds; routing waters to areas which restrict water flow such as a natural bog area at the end of a drainage ditch; or altering a waterway to create a marsh so there would be a larger plant to water surface area ratio, thereby facilitating the removal of as much water as possible by natural vegetation (Hazen and Beeson, 1979).

Impacts on wildlife could be mitigated by the maintenance of buffer zones or by reclamation. Timing is important, some endangered species of birds must not be disturbed during the nesting season. After this period mining could occur, reducing the possible impact. The reconstruction of habitats, trees, open waters, vegetation, etc., could be used on a small scale to enable some species to return (Minnesota Department of Natural Resources, 1981; Hazen and Beeson, 1979; Lofton, 1979), but those species requiring very specific habitats would probably be lost to the area. In Canada some peatlands cannot be developed because they are located in provincial and national parks. The International Biological Program, Project Telma, is compiling a list of peatlands with unique characteristics in Canada which should be protected (Monenco Ontario Ltd., 1981).

[1] Hemic peat is a moderately decomposed peat with a fiber content between 33 and 67%; sapric peat is a strongly to completely decomposed peat with a fiber content of less than 33%, (Washburn & Gilis Associates Ltd., 1981)

3.0 TRANSPORTATION AND STORAGE

The major impact from transportation and storage is associated with milled peat and its effect on air quality. The increased handling required during collection and transfer of milled peat to storage areas increases fugitive dust. Impacts are similar to, but may be greater than, those that occur during site preparation (Minnesota Department of Natural Resources, 1981).

Roads are usually constructed to transport peat from the bog. In Finland, trucks are used to transport peat up to 100 km. For distances between 100 and 300 km, railcars are used (Suoninen, 1982). The construction of roads can affect the environment in various ways. There can be a further loss of wildlife habitat, erosion and silting can occur when roads cross streams, and the hydrology of the area can be affected in ways similar to impacts of ditching and dyking. There would also be increased air pollution due to the exhaust emissions of the machinery, but this is not anticipated to be a major problem (Minnesota Department of Environment, 1981). Peat dust from loose uncovered stockpiles may be carried to other areas where, if it settles in sufficient amounts in the presence of certain microbes, it may constitute a fire hazard because of spontaneous combustion (Suoninen, 1982). With the use of heavy machinery there is a resulting increase in noise. Since most peatlands are located in areas of low populations, this may be an impact on wildlife populations.

Peat that has been hydraulically mined can be transported by truck (after screening for initial dewatering) or in a slurry pipeline. The impacts associated with transportation by truck are similar to those previously mentioned except that dusting is not a problem. A slurry pipeline would be used only when peat has to be transported a short distance. The associated impacts would be related to clearing a right-of-way for the pipeline. This would include the loss of some habitat and possibly siltation of streams crossed.

3.1 Mitigation

Wetting can be used to lessen the spread of peat dust. If the moisture level of a peat pile is increased by 2%, the threshold for wind velocity necessary to pick up the dust will be increased by 50% (Ertugrul and Sober, 1979). Another method to reduce peat dust originating at storage sites is to cover with tarp or plastic and compact the stockpiles (Minnesota Department of Natural Resources, 1981). Peat dust released during transportation of fuel peat could be reduced by using nydraulic trailer combinations that are side-tipped or that have back-discharging elevators and a maximal load volume to truck weight (Suoninen, 1982). During road construction, steps should be taken to control erosion and silting. Guidelines for road construction near streams and culvert designs for stream crossings are available in most provinces of Canada. These should be consulted for information on silt control, site clearing and rehabilitation.

SUMMARY OF ENVIRONMENTAL EFFECTS AND MITIGATIVE MEASURES RELATED TO PEAT HARVESTING

PROCESSES	POLLUTANTS	EFFECTS ON THE ENVIRONMENT	MITIGATIVE MEASURES
- Site Preparation (Drainage) - Mining (Release of Water)	- Release of Humic and fulvic acid	- Decreased PH - Increased acidity - Affects the solubility of metals*	add: - Hydrated lime ($Ca(OH)_2$) - Calcined lime (CaO) - Soda ash (Na_2CO_3) - Caustic soda ($NaOH$) use: - Holding Ponds
- Site Preparation (Drainage) - Mining (Release of Water)	- Release of disturbed water (With high suspended solids levels)	- Increased Turbidity** - Increased suspended solids load in receiving waters**	- Settling pond
- Site Preparation (Clearing Vegetation)	- Increased wave action in open water areas	- Increased Turbidity** - Increased Suspended solids levels in receiving waters**	- Wind Barrier (Snow Fence)
- Site Preparation (Clearing Vegetation)	- Release of nutrients (Nitrogen & phosphorus)	- Increased productivity of phytoplankton and algae, consequently there will be oxygen deficiency.	
- Mining (Dry harvesting)	- Peat Dust	- Respiratory processes biota may be affected.	- Use wind barrier
- Transportation	- Peat Dust	- Degradation of working environment.	- Reduced maximum load volumes - Using covered hydraulic trailer combinations that are sidetipped or that have back discharging elevators
- Storage	- Peat Dust		- Increased moisture by 2% - Cover peat with tarpaulins or plastic sheets - Compact piles

* Will affect the conductivity, if the solubility of metals increases, the conductivity will increase.
**Will decrease light penetration, resulting in decreased primary production.

4.0 PEAT DEWATERING PROCESSES

Production of fuel peat is severely limited in Canada due to the current reliance on solar drying and because of relative cost of production compared to other fuels. Because of the nature of the most frequently used dry mining techniques (sod mining and milling) and because they are used in combination with solar drying, peat production is limited to a few months in the summer. Also, large areas of peatland are required as only a thin layer of the peat (a few millimetres) can be mined each day. Hydraulic methods for mining peat provide alternatives to milling or sod mining and in certain climatic areas in Canada could make year-round operation feasible. Hydraulic mining techniques are not currently used commercially for fuel grade peat because of dewatering problems. (Hydraulic mining is presently used by Fisons Western Corporation for the production of horticultural peat.) At moisture levels below 70%, the water associated with peat is colloidally bound or chemisorbed and cannot be removed by traditional mechanical means (Monenco Ontario Limited, 1981). (Recent experimental work has indicated that it is possible to achieve 64% moisture (A. Ismail, Montreal Engineering Co. Ltd., personal communication to G. Gillis, 1983.))

Several peat dewatering processes which do not rely on mechanical dewatering have been developed. These range from solvent extraction and multiple-effect evaporation to beneficiation processes which enhance the thermal properties of peat in addition to improving dewaterability (Tsaros, 1981). For peat beneficiation, two closely-related processes, wet

carbonization and wet oxidation, have been suggested. Wet carbonization is a pre-utilization process and is discussed in detail below. Wet oxidation will be considered briefly here as it is actually a utilization process and is outside the scope of the work reported in this report. Pilot work on wet oxidation including a discussion of waste treatment technology has been described by Sheppard and McKim (1982).

4.1 Wet Carbonization of Peat

In the wet carbonization process, peat is subjected to elevated temperatures and pressures. Under these conditions decarboxylation occurs and peat is broken into lower molecular weight compounds. Many organic molecules are dissolved in the liquid phase of this process and carbon dioxide is given off (Smith, 1981; Tsaros, 1981).

The first patent for a wet carbonization process was granted in 1850 (Mensinger, 1980). The refinement of this process has continued into this century with pilot plants being operated in Sweden and Scotland. Small production-scale plants have been operated in Scotland and Russia (Mensinger, ibid.). Operations using this wet carbonization process have usually been plagued with operating problems such as corrosion of process equipment and unacceptable product quality. This process has not been used satisfactorily in production scale.

Two recently developed wet carbonization processes have been pilot tested and the potential for solution of the problems associated with previous processes appears promising. These two processes, the JP Energy OY Wet Carbonization Process, and the Koppelman Wet Pyrolysis Process, are both described in more detail in the following sections.

4.1.1 JP Energy OY Process

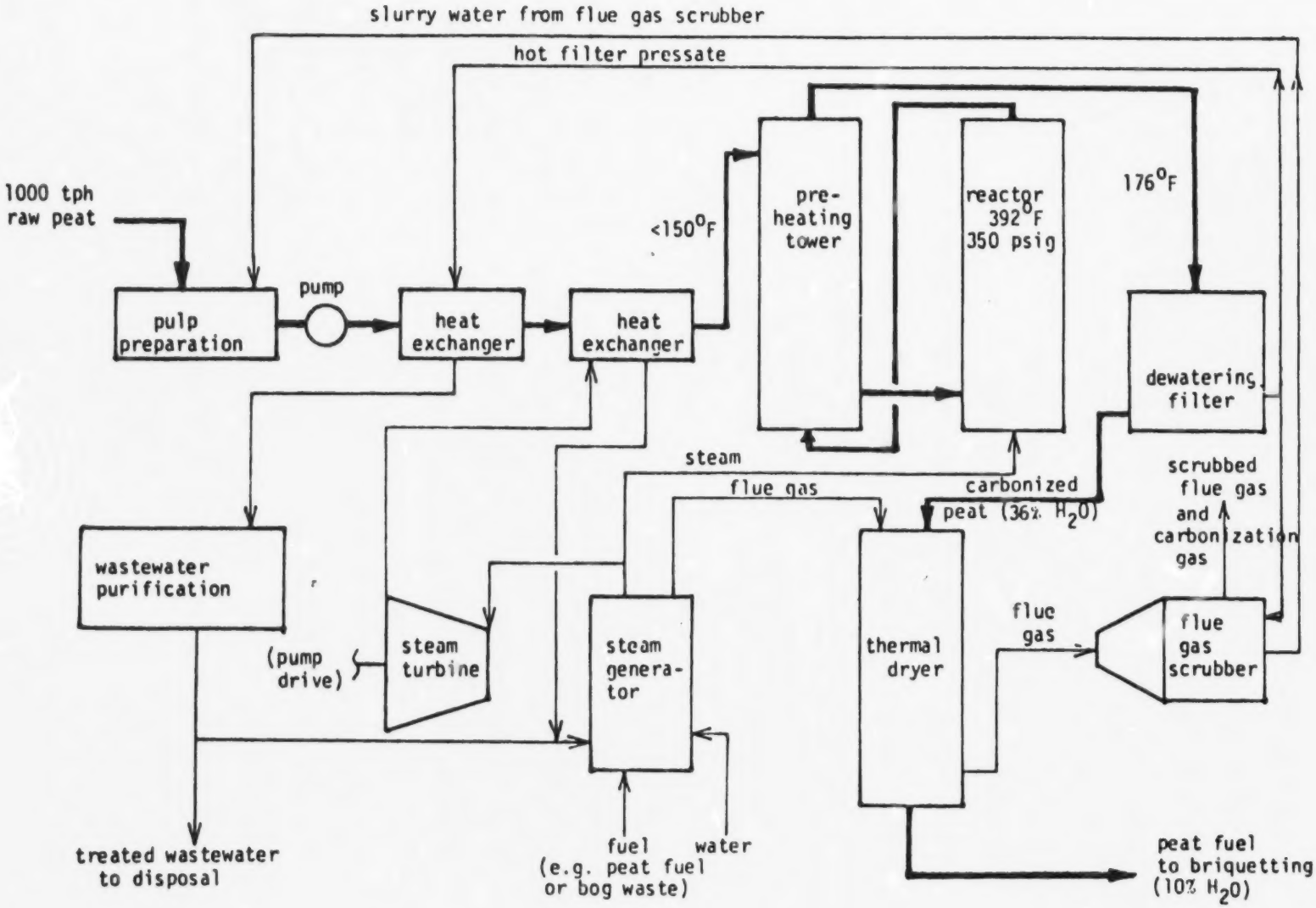
The JP Energy OY Process is based on technology developed in studies at the pilot plant level by Prof. B. Myreen of Turbu University, Finland. The following information is from descriptions of the process by Smith (1981), Monenco Ontario Limited (1981), and Mensinger (1980).

Two wet mining techniques have been proposed to obtain the peat for use in the JP Energy OY process. One technique is to mine the peat and transport it directly, without drying, to the processing plant by conveyor or truck. Water is then added to produce a pumpable slurry (approximately 95% moisture). Unwanted material such as roots and stones are removed by screening before the peat enters the process. Alternatively, the peat is diluted to a slurry in the bog and transported hydraulically to the processing plant. Figure 1 illustrates the JP Energy OY Process. The slurry is passed through two heat exchangers and a pre-heating tower to bring the temperature up to that required for the reactor. The first heat exchanger extracts heat from the filtrate of the dewatering filter and the second

Figure 1

Flow Diagram For JP Energy OY Process

(from Smith, 1981)



exchanger extracts it from back-pressure steam in the steam turbine exhaust. The slurry is reacted for 30 minutes at 392°F and 350 psig (200°C and 2.5 MPa) to produce a carbonized peat slurry.

Steam, from the carbonized peat slurry which has already passed through the pre-heating vessel, is used to heat the incoming slurry eliminating the need for heat transfer surfaces. Fouling problems are also avoided with this design. The carbonized slurry (at 80°C) is then dewatered in pressure filters to a moisture content of 50%. Following this, peat is dried in a thermal dryer heated by flue gas from the steam generator to a moisture content of 10%. The peat is then ready to be sent to a briquetting plant.

4.1.1.1 Waste Streams Associated with the JP Energy OY Wet Carbonization Process

Two types of waste streams from the JP Energy OY Process have been identified: an aqueous stream which consists of pressate (the aqueous effluent from the filter press) from the carbonized product, and a gaseous stream which is the flue gas from the thermal dryer (see Figure 1). No data from operating plants is available to characterize these waste streams. Laboratory data indicate that a large number of organic compounds would be present in both the liquid and gaseous waste streams (IGT, 1978). These data are presented in Tables 1 and 2. The scrubbing liquid can be blended with the feed effecting solids recovery.

Smith (1981) has also calculated a mass balance on the JP Energy OY Process. Based on a feed of 1000 tons of raw peat per hour, Smith has calculated that an aqueous stream of 918.8 tons/hr containing 8050 ppm soluble organics and a gaseous stream of 24 tons/hr (after scrubbing) would be produced.

Approximately 80% of the weight of the organics in the aqueous waste is contributed by methanol, acetone, and acetic acid. Table 3 gives the intrinsic biochemical oxygen demand (BOD) of these compounds.

TABLE 1

CALCULATION OF WET CARBONIZATION

WASTEWATER COMPOSITION

Liquid Sample Composition	mg/l
Methanol (CH_3OH)	1610
Ethanol (CH_3CH_2OH)	--
Acetone (CH_3COCH_3)	720
2-Butanone ($CH_3CHCOCH_3$)	160
Acetic Acid (CH_3COOH)	800
Propionic Acid	--
Pyridine (C_5H_5N)	40
2-Methylpyridine (C_6H_7N)	40
3+4-Methylpyridine (C_7H_9N)	10
Ethylpyridine (C_6H_6N)	8
Methylpyrazine ($C_5H_6N_2$)	91
2-Furaldehyde (C_4H_3OCHO)	8
5-Methylfuraldehyde ($CH_3C_4H_2OCHO$)	97
o-Hydroxybenzaldehyde (HOC_6H_4CHO)	--
Naphthalene	--
Methyl Naphthalene	--
Phenol (C_6H_5OH)	218
o-Cresol ($CH_3C_6H_4OH$)	1
m + p-Cresol ($CH_3C_6H_4OH$)	60
o-Methoxyphenol ($CH_3OC_6H_4OH$)	3
o-Ethoxyphenol ($C_2H_5OC_6H_4OH$)	
m + p-Ethoxyphenol ($C_2H_5OC_6H_4OH$)	63
2, 4-Xylenol [$(CH_3)_2C_6H_3OH$]	4
o-Ethylphenol ($C_2H_5C_6H_4OH$)	2
m + p-Ethylphenol ($C_2H_5C_6H_4OH$)	12
C_3-Phenol	3
C_4-Phenol	<1

From IGT (1978) Run No. PWC-3.

TABLE 2

CALCULATION OF WET CARBONIZATION

GAS COMPOSITION WEIGHT

Gas Sample Composition	Mole %
CO	2.19
CO_2	68.24
H_2	19.67
CH_4	5.91
C_2H_6	1.16
C_3H_8	0.51
$\underline{n}$-C_4H_{10}	0.26
$\underline{i}$-C_4H_{10}	0.13
H_2S	0.00
Furans (C_4H_4O)	0.51
Pyrroles (C_4H_5N)	0.13
Acetone (C_3H_6O)	0.39
Ethylene (C_2H_4)	0.64
Propylene (C_3H_6)	0.26
Total	100.00

From IGT (1978) Run No. PWC-3.

TABLE 3

BOD OF PURE ORGANIC COMPOUNDS
(Heukelekian and Rand, 1955)

Compound	BOD gm/gm Material	
	Range	Average
Methanol	0.13 - 1.12	0.79
Acetone	0 - 1.63	0.90
Acetic Acid	0.34 - 0.88	0.62

By considering the percentage by weight of these compounds in the waste, the BOD would be approximately 3000 ppm (assuming no inhibition of biological activity by other trace organics). Smith (ibid.) has suggested that the BOD may be as high as 4000 ppm.

4.1.2 Koppelman Process

A process involving the wet carbonization of peat has been developed by Koppelman in conjunction with The Stanford Research Institute (SRI International). The process as described by Philips et al.,(1979) and Smith (1981), involves initial mechanical dewatering of peat to about 70% moisture. Figure 2 is a process flow diagram taken from Smith (ibid.) The carbonization reactor in the Koppelman process operates under more severe conditions (400^{o}C and 10.5 MPa) than in the JP Energy OY Process. After initial dewatering, the peat is fed through a reactor by means of a screw conveyor and extruded as a product called K-fuel.

The reactor is externally heated. Steam produced in the downstream portion of the reactor is moved in a countercurrent direction to the peat material and condenses as it exchanges energy with the peat. As the peat leaves the reactor, its density is increased in an extruder and it is then cooled.

4.1.2.1 Waste Streams Associated with the Koppelman Process

There are no data available in the literature on the composition of waste streams leaving a reactor which processes peat by the Koppelman process. In the laboratory studies reported by IGT (1978), the temperature and pressure used were much lower than those occurring in a Koppelman reactor. From information published by Philips et al.,(1981), Smith (1981) has detailed the composition of gaseous and liquid effluent from a Koppelman wet carbonization reactor processing a bark feedstock. These data are shown in Tables 4 and 5.

Figure 2 Process Flow Diagram For Koppleman Wet Carbonization Process

(from Smith, 1981)

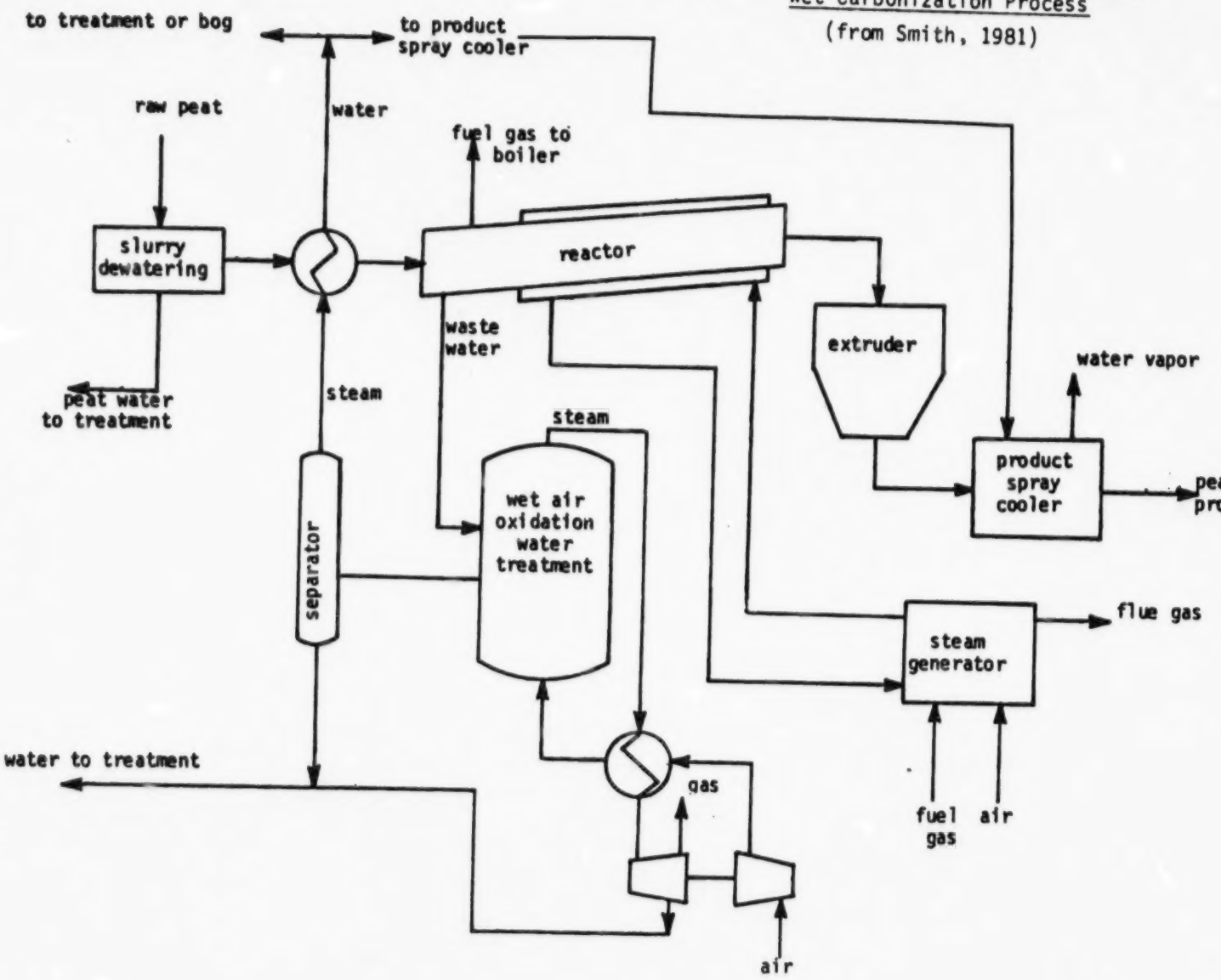


TABLE 4

REACTOR GAS CHARACTERISTICS FROM

THE KOPPELMAN REACTOR
(waste bark feedstock)

Component	Mole Percent
H_2	4.64
CO	7.74
CO_2	69.10
CH_4	11.21
C_2	3.84
C_3	1.73
C_4	0.69
C_{4+}	0.95
H_2S	0.10
	100.00

Source: Smith (1981)

TABLE 5

CHARACTERISTICS OF WASTEWATER FROM

THE KOPPELMAN REACTOR
(waste bark feedstock)

Temperature (^{o}F)	150
Soluble COD (ppm)	46,000
Soluble BOD (ppm)	24,800
Soluble TOC (ppm)	32,400
Phenols (ppm)	1,200
Ammonia-N (ppm)	30
Cyanide (ppm)	<0.7
pH	3.0

Source: Smith (1981)

A comparison of Tables 2 and 4 shows that the hydrogen content is lower and the carbon monoxide and methane content are higher in the Koppelman gaseous effluent than that produced in the laboratory studies. The differences may be due to the nature of the feedstock used rather than the process, however, with the more severe processing conditions in the Koppelman process, it is reasonable to expect the effluent characteristics to be different from the laboratory tests. In the case of the aqueous effluent, one might expect a high strength waste similar to that detailed in Table 5.

Smith (op. cit.) has calculated a material balance for the Koppelman process and has estimated the effluent volumes (based on 1000 tons/hr feed) to be 886.7 tons/hr of aqueous waste and 51.4 tons/hr of gaseous waste. Included in the aqueous effluent is 600 tons/hr of water removed mechanically which will have a chemical composition similar to bog water as it is removed before carbonization.

4.1.3 Other Wet Carbonization Studies

From laboratory studies on wet carbonization of peat by the Institute of Gas Technology (IGT), the composition of aqueous and gaseous waste streams was estimated (see Tables 1 and 2). In September 1980, IGT began design on a pilot-scale process development unit for carbonizing peat (Mensinger, 1980); however no published data are available on this process.

A process described as low severity peat dewatering has been studied by Chornet et al. (1981). In this process, which has been conducted on laboratory-scale equipment, peat at 8.5% solids content was macerated for five minutes and added to a continuous flow reactor. The process conditions varied from run to run, but the main features of the process are its relatively low temperature (190^{o}C) and short residence time (less than 1 minute). The reactor process involves the discharge of peat through an orifice which modifies its structure sufficiently to permit mechanical dewatering even at the relatively mild reactor conditions. After

reaction, the product is filtered. Two samples of filtrate were checked for organic strength. At a processing temperature of 90°C, the COD of the filtrate was 1790 ppm, and at 190°C it was 14,300 ppm.

4.1.4 Treatment of Wet Carbonization Effluents

The specific pollution control measures required will depend upon the size and location of a peat carbonization facility. It is not possible at present to exactly define the requirements for pollution control without more information on effluents such as would be obtained from pilot-scale and demonstration-scale plants. The following is a general discussion of the need for pollution control.

4.1.4.1 Air Emissions

At the feed end of the process where peat is handled in the wet state there is no fugitive dust problem. Dust problems arising from the handling of the dried product could be minimized by adopting practices and procedures used in other industries for handling dusty products (such as keeping loads covered during transportation).

Stack emissions from the JP Energy OY process are likely to be minimal since use of a scrubber is proposed as part of the process. In the Koppelman process, use of the gaseous effluent as a fuel to produce steam

has been proposed. Compounds such as carbon monoxide and hydrocarbons would be oxidized to carbon dioxide and water. The use of standard pollution control technology should provide adequate treatment of the flue gas coming from the boiler.

Because peat has a sulphur content in the range of 0.1 to 0.3 percent (Monenco Ontario Limited, 1981), the carbonization of peat should not lead to SO_2 emission problems.

4.1.4.2 Aqueous Emissions

The aqueous waste streams from a wet carbonization reactor have a high COD and BOD (see preceding section). Methods proposed for treating carbonization effluents involved either anaerobic treatment systems or wet air oxidation. Because of the strength of the waste, a two-stage anaerobic digestor system has been developed whereby in the first stage organic acids are produced and in the second stage, methane. The methodology is based on the ANTHANE process which is used for handling other high strength wastes such as distillary wastes and sugar beet wastes (S. Ghosh, Institute of Gas Technology, personal communication to O. Washburn, 1983). For the JP Energy OY process, an anaerobic process developed in Sweden (The ANAMET™ process) has been suggested (J. Rohrer, Wheelabrator-Frye Inc., personal communication to O. Washburn, 1983). After the anaerobic digestion, a further treatment such as a polishing lagoon would be used to achieve tertiary treatment before release of the effluent to the environment.

Processes such as the JP Energy OY process which require a slurry feed will require water to dilute the peat from its moisture content in the bog (which may be 85 to 90% moisture) to 95% moisture. To produce this slurry, one pound of water for each pound of 90% moisture peat would be required. This additional water when returned to the bog, even as a treated effluent, may cause flooding and runoff of peat waters into surrounding water courses if mitigative measures such as dyking are not taken (Smith, 1981).

An area of concern not covered by the literature is the release of heavy metals during peat dewatering. Rohrer (personal communication to O. Wasnburn, 1983) has suggested that mining of bogs known to be high in metals be avoided. If metals do end up in the aqueous stream, it may be possible to return the waste water to the bog with the treated effluent, but it would then be important to leave a sufficient buffer strip around the mined area so that water escaping to the surrounding area would be filtered through peat.

If elemental mercury is present in peat it could be discharged with the gaseous effluent and cause contamination problems. No data are available to estimate the severity of this problem for the dewatering processes being proposed.

The literature on the Koppelman process indicates an integral part of the process is a wet air oxidation reactor to treat the aqueous waste. There are no published data on the nature of the effluents generated during this process. They would probably require neutralization and biological treatment before release to the environment (Smith, 1981).

4.2 Partial Wet Air Oxidation of Peat

Wet oxidation is a process which has been used for many years to treat high strength aqueous wastes. Othmer (1981) and Smith (1981) have described processes for conditioning peat by partial wet oxidation. A recent experimental study involving both batch and continuous flow pilot plant experiments has been reported by Sheppard and McKim (1982).

In the presence of oxygen, combustion takes place at conditions near 200^{o}C. The process may be carried to completion (complete wet oxidation) or stopped after sufficient reaction has occured to break up the colloidal structure of the slurry and permit dewatering of the peat (partial wet oxidation). Complete wet oxidation can be used as an alternative to conventional combustion as a means of producing energy from peat. This process will not be discussed here since it is used to extract energy from peat rather than to dewater it.

Partial wet air oxidation differs from wet carbonization in that the heat for the process is generated from the oxidation reactions within the reactor. The degree of combustion and hence the reaction temperature is controlled by the oxygen supplied in the feed.

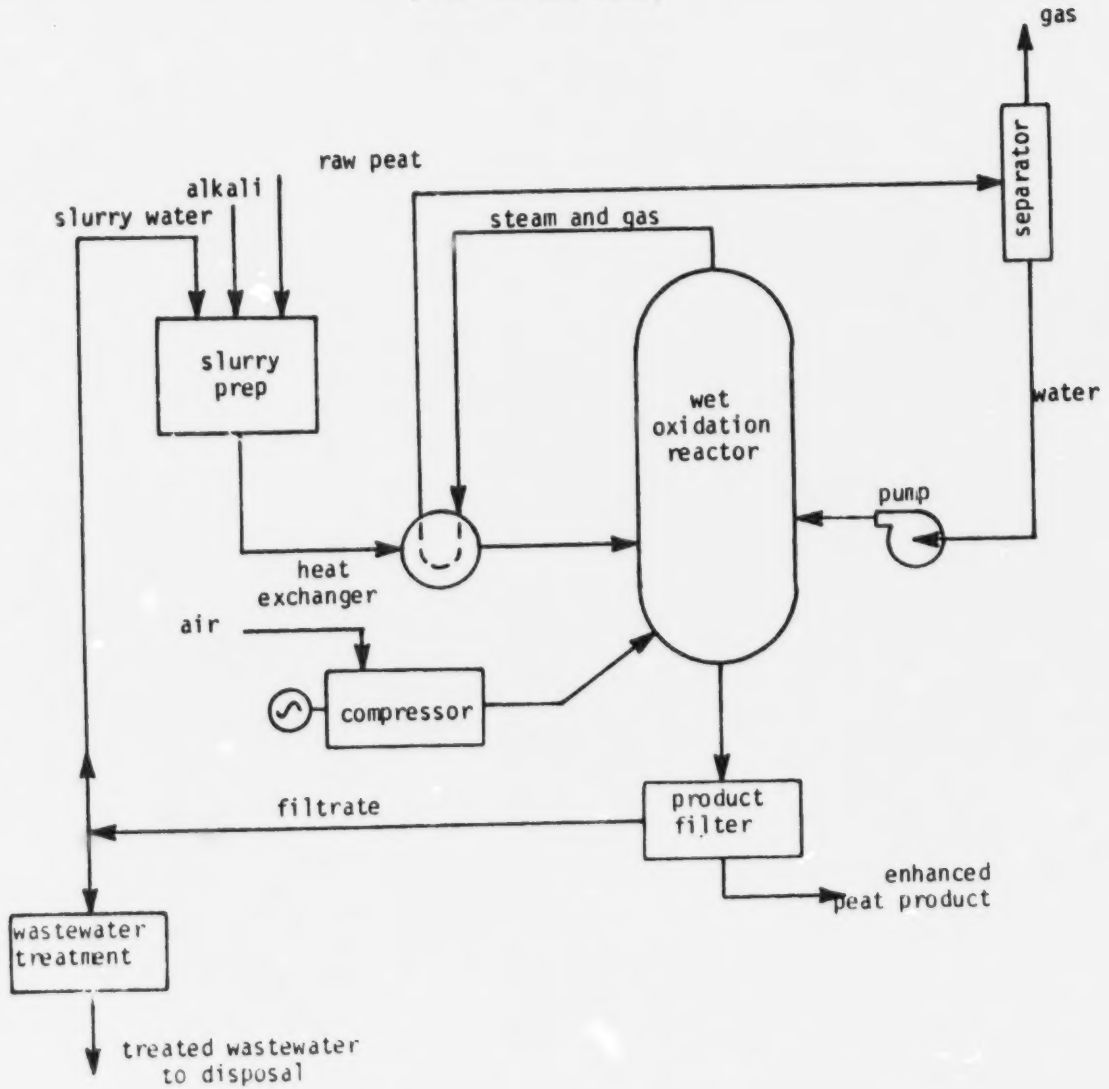
Figure 3 shows a process flow diagram for a partial wet oxidation process (from Smith, 1981). Alkali is added to the feed to catalyze the oxidation reactions. In calculating a mass balance for the process, Smith (ibid.) has estimated the effluent streams for a 1,000 ton/hr production rate to be 107.7 tons/hr reactor gas and 878.3 tons/hr wastewater.

Sheppard and McKim (1982) have analysed a system whereby the wastewater from either total or partial wet oxidation is treated by anaerobic digestion followed by aerobic treatment. The anaerobic digestion was considered to be not only a means of waste treatment but as an important contributor to the energy production through the evolution of methane gas. Bench scale experiments were carried out for anaerobic/aerobic treatment of wet oxidation effluents. Although loading rates were not established it was demonstrated that the process would work in principal and that a biogas rich in methane (70-75%) could be produced.

Figure 3

Preliminary Process Flow Diagram for Partial Wet Oxidation of Peat

(from Smith, 1981)



4.3 Other Dewatering Techniques

The Institute of Gas Technology has investigated solvent extraction as a dewatering technique for peat (Tsaros, 1981). Their laboratory studies have indicated that solvent extraction is not economically competitive with other dewatering processes.

Other concepts such as centrifugation and multiple effect evaporation have been briefly reviewed by Tsaros (ibid.). Work on these processes has not proceeded beyond the conceptual stage and no information is available on the effluents generated or their treatment.

The methods of peat dewatering discussed previously in this section are those that would be associated with a large-scale peat energy development. Many of these processes include mechanical or thermal dewatering as unit operations in the overall process. In some specialized cases, for example that of Fisons Western Corporation in British Columbia, which processes horticultural-grade peat, dewatering may be accomplished by using only conventional mechanical and thermal processes.

Reviews of mechanical dewatering and thermal drying equipment have been presented by Monenco Ontario Limited (1981) and Tsaros (1981). The water from a mechanical dryer would have similar characteristics to bog water and could be returned to the bog (see earlier section on water removal prior to Koppelman process).

The exhaust from thermal dryers will require particulate control. In the JP Energy OY Process a scrubber is proposed. Tsaros (ibid.) suggests a cyclone to remove particulates from the exhaust of a fluidized bed dryer.

4.4 Briquetting

Following dewatering, it may be desirable to convert the peat physically to a form which is easily handled and transported. Briquetting provides a means of preparing a suitable product.

If milled peat is used for briquetting, a thermal drying stage is required before the briquetting process. Monenco Ontario Limited (1981) has described a briquetting factory built by Outokumpu OY of Finland in which peat was burned in a fluidized bed burner to generate heat to dry milled peat from 40-55% moisture to 12-15% moisture suitable for briquetting.

Peat fines are separated from the dryer exhaust by a series of cyclones followed by a venturi scrubber. The effluents from the process have been identified as flue gas and scrubber water. The latter is circulated through a holding pond and reused. Settled solid material from the pond is removed once a year and disposed of as solid waste. Yanushevskii and Zinina (1980) have characterized the aqueous wastes from two briquetting plants in the U.S.S.R. They found that 99% of the solids were removed with a settling pond that had 24 hours retention time. The COD

of the effluent was found to be 291 ppm for one plant and 443 ppm for the other.

Since peat is handled in the dry state there exists the possibility of high fugitive dust levels, both within and outside the plant. Berezhnoi (1980) has suggested the use of sprays to keep down dust levels with the water drained off to a settling pond. This method has been used successfully in a factory in the U.S.S.R.

5.0 SUMMARY AND CONCLUSIONS

Although peat is harvested for energy use in various countries, there has been little development of technology for abating pollution from the harvesting and pre-utilization processes. There are few examples of existing operations where pollution abatement technology has been applied.

Impacts common to both wet and dry mining techniques include disruption of extensive habitat which may be critical to particular flora and fauna, and effects on hydrology or hydrogeology. Long-term degradation of habitat may be avoided through careful planning of the mining operations and by use of appropriate reclamation plans. The impacts on hydrology and hydrogeology are poorly understood, and mitigative measures have not been designed to specifically address these concerns. Removal of particulates is a major concern with respect to drainage from dry mining operations and from wet mining (should effluents be returned to the bog). Both filtration dams and settling ponds are considered useful for reducing the particulate levels of effluents.

Coping with fugitive dust is a major problem, particularly relative to dry mining techniques. Techniques for limiting this include such measures as the erection of barrier fences to reduce exposure of the site to winds. In wet mining methods, large amounts of water may be added during mining or during movement of slurries. Following mechanical dewatering, it is suggested that this water be returned to the bog as the

water is considered to be similar to source bog water. However, there is concern about potential impacts to site hydrology due to increased water volumes. It has been suggested that a buffer strip of peat be left around the area which receives water produced during dewatering of the hydraulically-mined peat. This buffer strip will act to intercept particulates and may buffer runoff flows.

There are no long-term studies on production-scale plants which delineate the composition of waste streams produced during either wet carbonization or wet oxidation. The information available on waste streams from these processes is based on laboratory bench-scale tests or pilot tests. The composition of waste streams has been determined from such tests for several proposed processes. Treatment techniques have been described for handling these wastes. The goal of wastewater treatment is to lower the BOD and COD, and remove organics through anaerobic or aerobic treatment. In certain cases, effluents from these treatment systems require polishing prior to release into the environment.

Although there is no mention in the literature of metals being released during any of the pre-utilization procedures described, a potential problem exists in particular areas where high concentrations of metals occur in peat. These metals may be released to the aqueous environment or to the air (i.e. certain metals may be volatilized under process treatment conditions).

The technologies associated with pollution abatement for all phases of harvesting are based on existing technologies in place in other industries. Their effectiveness at reducing particulates is well established.

In conclusion, until there is information available from production-scale operations for wet carbonization or wet oxidation, it is difficult to assess the effectiveness of proposed treatment systems described in the literature. It is not clear whether techniques proposed for control of effluent from wet carbonization or wet oxidation will be effective in production-scale operations. The effectiveness of these processes in controlling levels of metals in effluents is not known. More attention should be paid to the potential for metal release. This requires detailed investigations of waste streams from the various processes. The effluent from mechanical dewatering of fuel peat should be analysed for both metals and organic contaminants. It has been assumed that this effluent is similar to existing bog water, however data should be collected to confirm this.

Although the hydrology and hydrogeology of peatlands has been the subject of many studies, the effects of mining on these aspects is still not clear. Information on these effects should be obtained prior to large-scale development of the peat resource.

6.0 INDEX TO ABSTRACTS

SUBJECT	ABSTRACT NUMBER
Site preparation and mining	1, 4, 7, 8, 9, 10, 11, 13, 14, 15, 19, 20, 23, 24, 28, 32, 33
Transportation and storage	15, 23, 32
Mitigation of impacts	2, 5, 10, 12, 15, 16, 18, 21, 23, 24 26, 31, 32
Peat dewatering	6, 24, 29, 34
Wet carbonization	17, 22, 24, 25, 27, 30, 34, 35,
Other dewatering techniques	24, 25, 29, 30, 34
Treatment of effluents	3, 30

1. Aspinal, F., and W. Hudak. 1980. Peat harvesting - state of the art. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. Dec. 1-3, 1980. pp. 159-173.

   Large-scale peat harvesting methods are presently under study by Dravo Engineers and Constructors, a unit of Dravo Corporation, as part of a contract awarded to the Institute of Gas Technology by the Gas Research Institute.

   The development of a reliable, efficient, economical, and environmentally acceptable harvesting and reclamation plan is crucial to the success of a peat fueled project. Several harvesting options are available, but no one system is best suited for all bogs. An integrated harvesting plan must be selected that addresses the trade-offs between cost, reliability, and environmental impact. Factors such as bog and peat characteristics, transportation distances, operating and reclamation requirements, and desired final product will determine which production system is best suited for a specific site.

   This paper discusses the state of the art of large-scale peat harvesting methods, and briefly describes the equipment required and other factors which impact the extraction of peat for use as an energy source.

2. Benes, P., E.T. Gjessing and E. Steinnes. 1976. Interactions between humus and trace elements in fresh water. Water Res. 10:711-716.

   The interaction between humus and 18 elements in lake water has been studied using centrifugation, ultrafiltration and filtration through ion exchange membranes. The fractions of humus and trace elements separated by these methods were determined spectrophotometrically and by activation analysis, respectively. Samples of the unconcentrated water and those concentrated 5-50 x were analysed. It has been found, that the association is probably very low for halogenes and alkali ions. Alkaline earths and particularly the trivalent metals are associated with humus to a rather high degree. Transition elements also may strongly interact with humus in lake water.

3. Berezhnoi, S.A. 1979. Method of combatting peat dust. Torf. Prom'st.9: 23-25.

Reviews the development and testing by the Kalinii Polytechnical Institute of an air/vapour method of settling suspended peat dust in peat-briquette factories. When tested at Vyshnevolotsk peat-briquette factory a portable vapouriser based on this method, consisting of a nozzle and flexible hose, reduced the dust content of the air by 2-4 times and the temperature by 5°C while raising relative humidity by 30-47%. The recommended nozzle design incorporates an axial air input and a tangential water supply. Discusses the application of this method to factories using Peco and air/flue-gas dryers.

4. Brooks, K.N., and S.R. Predmore. 1978. Final report, phase II - peat program, hydrologic factors of peat harvesting. Minnesota Department of Natural Resources. 36 p.

This report describes the hydrologic characteristics of natural peatlands, methods of peat harvesting, and the expected impacts of peat harvesting on water resources. Lake States, Canadian and European experiences are reviewed and coupled with the characteristics of Minnesota peatlands to estimate harvesting impacts.

5. Buggie, W.J. 1981. Peat harvesting in New Brunswick, an engineering proposal for on-site water treatment. Report for partial fulfillment of degree in forestry engineering submitted to the Department of Forest Engineering, University of New Brunswick. 32 p.

Peat harvesting affects peat bog drainage by increasing runoff, and by contaminating the ecosystems downstream with peat silt, nutrients (nitrogen and phosphorus), and mineral and organic acids.

In this study a water treatment system containing a settling pond and a filtration dam is proposed (1) to hold one-in-two year stormflows, (2) to allow half of this water to pass through the system in three days. Crushed limestone, spread along the discharging side of the filtration dam, is used to neutralize the runoff. This system, according to a quick cost assessment, is economically feasible.

6. Chornet, E., K. Farrell, R. Overend and C. Roy. 1981. A low severity peat dewatering technology. In: Conference on peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1, 1981. pp. 217-237.

   Thermal dewatering of fuel peat has been in existence since the early part of this century. The reasons for its development have been that "conventional" air drying of fuel peat results in seasonal operation and poor economics primarily due to the low capital utilization factor. Hydraulic mining, e.g. dredging, followed by thermal dewatering offers better capital utilization though at the expense of part of the harvested peat utilized as fuel in the drying process often described as "Wet Carbonization". Experiments on the rapid passage of peat slurries through a heat exchanger followed by expansion through a nozzle and filtration to produce a handleable peat with <50% moisture will be described. The process can be conducted at 190°C with residence times of <60 seconds; based on the experimental mass and energy balance, it is estimated that the overall thermal efficiency in a commercial scale plant will be >75%. The extremely short duration of thermal treatment and the rapid expansion appear to disrupt the structure of the peat which suffers a partial hydrolysis.

7. Clausen, J.C. 1980. The quality of run off from natural and disturbed peatlands. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 523-532.

   The results from the first two years of water quality sampling of the run off from four peatland watersheds is reported. Two of these peatlands are drained, one under cultivation and one being mined, while the other two are undisturbed. Comparisons indicate that the disturbed peatlands had higher concentrations of colour, suspended sediment, acidity, potassium, iron, aluminum, and sodium. For all peatlands, spring minimum values occurred for pH, alkalinity, specific conductivity, calcium, magnesium, colour, and nitrogen. Maximum values of suspended sediment occurred during spring as expected, the minerotrophic fen run off had higher values for pH, alkalinity, specific conductivity, calcium, and magnesium than did the ombrotrophic bog.

8. Clausen, J.C. 1979. The potential effects of peat mining. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-24, 1979. pp. 201-203.

   Critical energy shortages in the U.S. have resulted in a search for alternatives to traditional fossil fuels. One such alternative includes peat as a fuel for both gasification and direct burning. Because peatlands are eventually extremely wet environments, the mining of peat may result in changes in both water quantity and quality. Surface water quality effects of greatest concern are impacts of peak flows, the distribution of flow throughout the year, and total annual flow. The effect of peat mining on the local and/or regional ground water resources is also of concern. Potential impacts of peat mining on water quality involve such parameters as pH, acidity, suspended sediments nitrogen, phosphorous and various metals.

   The potential effects of peat mining on water resources vary with a number of factors, including peat type and depth, peatland type (bog or fen), the method of mining, the location of the mining operation in the watershed, and climate.

   Generally, peat mining operations that require drainage (milled and sod peat) are likely to reduce peak flows and increase low flows and total annual flow. The net result is that flow is redistributed more evenly throughout the year. Peat mining requiring drainage also has the potential to increase suspended sediment and nutrients in discharge waters.

9. Clausen, J.C., and K.N. Brooks. 1980. The water resources of peatlands. A literature review. Prepared for Minnesota Department of Natural Resources, Minnesota Peat Program. 143 p.

   Hydrologic characteristics of peat, the hydrologic cycle of peatlands, and the effects of drainage and timber harvesting are addressed under water quantity. In the second section, water quality of natural peatlands, chemical content of peat, the significance of water quality parameters and the effects of agriculture, forestry and peat mining on water quality are discussed.

   Forestry, agricultural and mining of peatlands have the potential to modify both water quality and water quantity of Minnesota's peatland.

10. Clausen, J.C., K.N. Brooks, and D.P. Guertin. 1981. The water resources of peatlands - summary of two-year results. Prepared for the Minnesota Department of Natural Resources, Minnesota Peat Program. 101 p.

This report is a summary of two years' field work on the water quantity and quality of Minnesota peatlands. The water quantity results includes information on water budgets, stormflow, groundwater flow, water table fluctuations and infiltration. The water quality results included information on the study areas, nutrient loading, mining effects, reclamation effects, downstream assimilation, and water quality relationships.

11. Clausen, J.C., J.R. Lewis, K.N. Brooks, and D.P. Guertin. 1980. The quality of water discharged from Minnesota peatlands. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. p. 533-537.

Results from the first year of water quality sampling of the stream flow from 39 Minnesota peatlands indicate that the natural range in water quality is quite broad. Regional water quality trends were not obvious, but the water quality of bogs was quite different from fens. As expected, fen streamflow was higher in pH, specific conductivity, alkalinity, calcium, magnesium, iron, sodium and manganese. Fens were higher in suspended sediment and total nitrogen while bogs were higher in colour, acidity, and mercury. Fens also had a greater range in water quality values than bogs. Peatlands were classified based on six water quality characteristics and classifications agreed well with the watershed characteristics of peat type with pH.

12. Costle, D.M., J.D. Denit, D.C. Ruddy. 1981. Development document for proposed effluent limitations guidelines new source performance standards and, pretreatment standards for the coal mining point source category. Published by Effluents Guidelines Div., Office of Water and Waste Management, U.S. Environmental Protection Agency, Washington, D.C. 429 p.

This report presents technical data by EPA with reagrd to pollutants from coal mining and their treatability under the Clean Water Act. Treatment technology was assessed to determine best available and upon which to base new performance standards. The need for establishing regulations to limit mine discharge after

mine production ceased was also assessed. Finally existing effluent limitations during rainfall and snowmelt were reviewed and where necessary, augmented.

13. Crawford, R.L. 1978. Effects of peat utilization on water quality in Minnesota: final report and recommendations to Minnesota Department of Natural Resources. March 1978.

    There is a large volume of scientific literature concerning water chemistry as it relates to waters present in peat bogs. The author has assembled several hundred papers concerned with this topic, covering research carried out between about 1890 and 1977. Unfortunately, there is much redundancy in this literature. Also, only a very small fraction of the total is directly relevant to the task at hand - prediction of water quality effects that might result from extensive mining of peat resources. Main, relevant points gleaned from the literature search are presented.

14. Ertugrul, A.M., and R.F. Sober. 1980. An introduction to environmental considerations of peat developments, with reference to air and water quality. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. Dec. 1-3, 1980. p. 603-616.

    The purpose of this paper is to provide a general overview of environmental regulations applicable to a commercial-scale peat extraction and processing operation, and its support facilities. Following the general overview, air and water pollution aspects of peat development are discussed in detail. Interactions between water quality and hydrology are also discussed in detail.

15. Ertugrul, A.M., and R.F. Sober. 1979. Effects of peat harvesting and gasification on air quality. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-24, 1979. p. 172-178.

    Major identified potential sources of airborne pollutants from commercial peat harvesting and gasification operations are: peat harvesting, storage, handling, and crushing operations, claus sulfur plant and other process gas vents, flue gas from plant boilers, exhaust emissions from vehicular traffic and

heavy machinery, and secondary sources resulting from peat mining and gasification projects. These sources are similar to those expected in coal mining and gasification operations of comparable size.

The major potential air pollutants from the sources listed above are particulate pollutants, sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and aldehydes. Among these potential pollutants, particulates, SO_2, NO_2, reactive hydrocarbons, and CO are regulated by the National Ambient Air Quality Standards (NAAQS), as established by the U.S. Environmental Protection Agency (EPA) under the requirements of the CLean Air Act of 1970 (CAA).

An analysis of the design of a peat gasification plant based on the IGT PEAGAS℠ Process shows that air pollution control techniques developed for coal gasification plants can limit pollutant emissions to within New Source Performance Standards (NSPS). This is facilitated by the relatively low sulfur content of peat. Computer simulation of air pollutant dispersion from a PEATGAS plant producing 80 x 109 Btu/day of SNG shows that Prevention of Significant Deterioration (PSD) requirements for a Class I Area could be met within as close as 10 miles to the plant facility. It is estimated that emissions of fugitive peat dust from a hydraulic peat harvesting operation would be negligible. Various control measures are available to deal with emissions resulting from other types of harvesting techniques as well as associated activities such as storage and handling.

16. Hazen, C.B., and R.J. Beeson. 1979. Techniques for the assessment of bog hydrology, harvesting and mitigation of water quality impacts resulting from peat harvesting. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-29, 1979. p. 219-240.

Large-scale hydraulic peat harvesting will involve control of surface and groundwater flows over large areas. A preliminary water budget indicates that civil works associated with this operation will provide sufficient water for a PEATGAS plant operation.

Peat harvesting techniques, local hydrology, and reclaimed land-use options are so interrelated that a comprehensive plan embracing all three of these areas must be formulated prior to actual development.

In an integrated peat harvesting/water quality/land-use plan, the adoption of a multiple land-use/reclamation concept enables tailoring of the hydrologic response over a wide range, including "duplication" of preharvest conditions.

Although additional field work is necessary, the use of natural processes to mitigate water quantity and quality impacts may greatly reduce the time and energy required to construct civil structures for water quantity and quality control.

The conceptual framework developed in this paper delineates the advantages of combining "dry" and "wet" techniques of peat harvesting. Where applicable, combinations of the primary techniques suggest a more reliable and flexible means for peat harvesting.

To adequately characterize the hydrologic system of a bog area, the concept of the reference watershed was developed. Data obtained by monitoring this reference watershed would provide hydrogeologic boundary conditions necessary for developing a comprehensive peat harvesting/water quality/land-use plan.

Cold weather design and operating conditions must be considered for peat harvesting in the proposed Minnegasco lease area. These considerations will manifest themselves in areas ranging from slurry pipeline protection, through harvested-peat storage and harvesting rates, to spring break-up preparations. Special harvesting, transportation, and seasonal preparations are conceivable using the advantage of frost penetration to provide for surface transportation, ditch preparation, and, perhaps a variation in backhoe or heat/steam harvesting.

17. Institute of Gas Technology. 1978. Experimental program for the development of peat gasification. Interim Report No. 4.

    This report presents results of tests conducted to determine the physical properties of Minnesota reed sedge peat. The objectives were to obtain engineering data and develop a model for peat gasification, to select a peat gasification process and to determine its economics.

18. Kaminskiy, V.S., and I.V. Orlov. 1979. Effect of peat mining on surface-water quality. Translated from Gidrotek. Melior. 10:71-74.

Wastewaters from the natural and man-made peat deposits in the Ivan'kov basin were analysed for chemical components. Ca^{2+} was the main cation and HCO_3^- the major anion. Humic acid concentrations were 6 to 57 mg/L and fulvic acid 10 to 131 mg/L. Phenols and H_2S were absent. A significant influence on the components of the wastewater was the presence of nitrogen and phosphorous resulting from the preparation of peat-fertilizer products. Ozonization was an effective process for reducing the colour of the wastewater. The optimum amount of ozone was 2-4 mg/L. Also successful radiation with fast electrons; 350 J/kg was effective when the wastewater was aerated and 500 J/kg was needed in the absence of aeration. Colour, odour, and taste were improved and toxicity decreased. Phosphorous could be removed without difficulty and nitrogen could be eliminated by the use of biological filters.

19. Korpijaakko, E., and P.E. Pheeney. 1976. Transport of peat sediment by the drainage system from exploited peatlands. Proceedings of the 5th International Peat Congress, Poznan, Poland, September 21-15, 1976. p. 135-148.

Contains findings of an investigation on the effect that the drainage of a peatland for commercial exploitation might have on an adjacent aquatic environment.

Both the water and the bottom sediments were sampled. The analyses consisted of the measurement of pH, transmittance of light by the water samples, identification of sediment components and the quantity of sediments on the bottom.

The first results indicate that the discharge of waters from the investigated peatlands does not affect the pH values of the receiving streams. There is an indication that the mode and the age of operation have a significance in the transport of sediments, but that it is strongly modified by the length of the discharge channel outside the peatland. Short-term variations due to the spring run-off and an accelerated run-off after heavy rain storms have their own effect, too.

20. Lofton, S.M. 1980. Heterogeneity of ecological factors affecting commercial development of selected North American peat deposits. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1-3, 1980. p. 595-616.

A variety of techniques may be required for commercial development of North American peat desposits due to the

heterogeneous nature of the ecosystems in which commercially exploitable peat occurs. This paper outlines some of the salient ecological features observed in various peat extraction operations in the U.S. and Canada.

21. Lofton, S.M. 1979. Peat: ecologically sound resource development. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-29, 1979. p. 189-199.

In today's world, any resource management plan must be viewed in terms of overall system stability. A system is defined as anything that functions as a whole by integration of organized parts. The order of a system, whether it be a single organism or a large peat bog, is based upon and maintained by energy. The ultimate goal in any resource development plan must be maintenance of system stability. Any ecosystem disturbance that results in a situation in which energy input exceeds energy yield is unacceptable in terms of ecologically sound resource management.

Peatlands occur in all portions of the world. Wherever waterlogging creates anaerobic conditions, peat may accumulate due to low-level decomposer activity in organic materials. Because peat occurs in a large variety of ecosystem types, ecologically sound management of these valuable natural resource deposits must employ a variety of methods. Sound management of some peat deposits may be simply preservation. Local conditions will dictate development practices for other deposits.

A whole-system approach to peat development is recommended. A team consisting of hydrologists, air quality specialists, biologists, geologists, soil scientists, and engineers should be organized to study the peat system, plan the best method or methods of development, and implement plans. Computer modeling and pilot projects are recommended to incorporate available information and add to our understanding of peatland dynamics. A number of techniques are available for successful reclamation of postharvest areas. Many are currently being tested in a variety of research projects in the United States, Canada, and Europe.

Using the best available technology, ecologically sound development of selected peat resources appears promising if proper team effort is employed through the project.

22. Mensinger, M.C. 1980. Wet carbonization: state-of-the-art review. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1-3, 1980. p. 249-280.

Peat, in its naturally occurring state, contains as much as 90 weight percent water. To use peat as a source of energy, the bulk of this water must be removed in an energy-efficient manner using either mechanical methods or solar energy, without the use of fossil fuel. Solar drying is an energy-efficient method, but its success is heavily weather dependent. Mechanical dewatering (pressing) methods, similar to those used for dewatering sludge and paper pulp, can reduce the peat moisture content to the range of 70% to 75%. However, thermal drying is required to achieve lower moisture content.

One of the pretreatment methods that facilitates the mechanical dewatering of peat to 50 weight percent moisture is wet carbonization. In this process, wet peat is heated under pressure to temperatures in the range of 300° to 1000°F from 5 to 60 minutes of residence time. Wet carbonization of the peat also removes a fraction of the oxygen from the peat by decarboxylation and dehydratization reactions. Wet-carbonized peat can be readily dewatered to less than 50 weight percent moisture.

This paper reviews the development and state-of-the-art of wet-carbonization processes beginning with M. Ekenberg's process in England and Scotland in the early 20th century to those of others in Sweden, the U.S.S.R., Germany, and more recently, Finland and the United States.

23. Minnesota Department of Natural Resources. 1981. Minnesota peat program final report. Prepared by the Minnesota Department of Natural Resources. Division of Minerals. August 1981. 93 p.

A summary is presented of five years' work evaluating the environmental, social, and economic consequences resulting from the development of peatlands.

Peatlands are a valuable resource and since our knowledge of it is changing policies for utilization should be kept flexible.

24. Monenco Ontario Limited. 1981. Evaluation of the potential of peat in Ontario. Ontario Ministry of Natural Resources, Mineral Resources Branch. Occasional Paper No. 7, 193 p.

An overall review of the possible uses and the opportunities for development of the peat resource in Ontario. The peat resources of Ontario were assessed. The following areas were considered, peat mining, peat processes, potential applications of peat in Ontario, environmental considerations, regulatory guidelines.

25. Othmer, D.F. 1981. Peat Processing by wet air oxidation. In: Conference on peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium. Virginia, December 1, 1981. p. 347-354.

Peat contains up to 19 times as much water as solids. Most the of water cannot be removed mechanically; and drying may require twice as much heat as given by the combustion of the solids. At 300^{0}F (150^{0}C) in a closed vessel, added air burns peat suspended in water. A minimum of air partially oxidizes the peat-water bond; and on discharge, the solids can be separated readily, containing less than one part water. The peat now can be dried or burned as a fuel.

Sufficient air burns peat completely by this wet air oxidation (WAO) to give its full heat, which, compared on a dry weight basis with coal, is from two thirds to an equivalent heating value. The WAO is, however, with wet peat more efficient in conversion of this heat to steam than a modern coal fired boiler (CFB) and the percent of CO_2 in the exhaust gases may be almost twice that in the CFB stack gases.

The cost of a WAO unit may be about the same as for a CFB burning dry coal; and the costs of operating each are also about equivalent - without regard to the costs of the respective fuels. Thus the substantial saving realized in generating steam or power from wet peat, where available, will be the difference between the cost of its harvesting and delivery to the power station as compared to the cost; including transportation of the dry coal. A method is suggested for harvesting wet peat from the wide expanse of a peat bed, and its delivery and burning in a central station for WAO and power generation.

26. Peer Consultants Inc. and Brehm Laboratory. 1983. Treatment of mine drainage from abandoned mines by biological iron oxidation and limestone neutralization - Phase I Report, U.S. Bureau of Mines Contract No. J0113033. May, 1983. 13 p. + tables.

This report presents Phase I of a two phase project to look at an alternative to the acid mine drainage (AMD) problem. Sphagnum moss is being used to reduce acidity and iron content. A portable bog system of 6 multisectioned plexiglass chambers (first 5 contain live sphagnum, last one contains coarse limestone), mounted on a steel flat-bed trailer. Water containing AMD was pumped into the portable bog and tests were done at various points in the bog to determine concentration of metals, cation exchange capacity of the sphagnum and acidity of the water.

There was no significant change in the acidity of the water coming through sphagnum but a reduction in acidity of 43-90% after the water passed through the limestone chamber. Up to 97% of the ferrous iron and 72% of total iron was removed. Throughout the 8 week trial run and 16 week test run the sphagnum retained its cation exchange capacity.

27. Phillips, R.C., R.G. Murray, and E. Koppleman. 1979. Peat dewatering and upgrading by the Koppleman Process. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-24, 1979. p. 147-157.

The Koppelman process for irreversible drying and upgrading of low value fuels has been applied to peat from various sources. The paper describes an adaptation of the Koppelman process in which peat is hydraulically mined and pipelined as a slurry to a plant where it is converted to a high quality solid fuel, designated as K-fuel.

In the Koppelman process wet feedstocks are heated under pressure to achieve partial carbonization. Water and carbon dioxide are displaced and the product has a high heating value, typically 4000 to 5000 Btu/lb higher than the heating value of conventionally dried peat due to the removal of oxygen. K-Fuel made from peat has a heating value up to 14,000 Btu/lb, depending on ash content and severity of treatment. This fuel can be burned in a solid fuel-fired burner or can be ground and dispersed readily in fuel oil to burn as a slurry.

Thermal pretreatment converts the peat for a form that can be partially dewatered by filtration. The dewatered peat is then conveyed through the reactor where it is

heated further to partially carbonize the peat. The product is extruded from the reactor, then cooled and chopped into a convenient form. Water from the reactor can be treated by wet air oxidation to reduce the organic content and to generate the steam required by the process.

28. Reed, R.M., L.D. Voorhees, and P.J. Mulholland. 1981. Overview - using peat for energy: potential environmental constraints. In: Peat as an energy alternative II. Proceedings of the Institute of Gas Technology Symposium. Arlington, Virginia, December 1-3, 1981. p. 675-691.

Serious consideration is being given to using peat as an energy resource in Minnesota, North Carolina, Florida, and some New England state. Advantages of using peat in this way are many: (1) significant peat deposits occur in regions having limited indigenous supplies of other fossil energy resources; (2) technologies for mining and burning peat have already been proven in other countries; (3) mining peat does not require removal of extensive overburden; and (4) the possibilities of reclaiming mined peatlands to productive uses are promising.

Potential environmental constraints for using peat as an energy resource are associated with disruption of important regional wetland ecosystems. Mining peatlands may significantly modify ground and surface water hydrology, degrade water quality in downstream receiving systems, contribute to the deterioration of local air quality, disrupt or eliminate plant and animal populations having specialized requirements and limited distributions, and destroy unique wetland ecosystems representing important scientific and educational resources. Careful selection of peatlands to be developed and application of appropriate mitigation and monitoring programs will be necessary to offset these impacts.

Data on emissions and effluents from commercial operations of peat energy facilities are not currently available. Environmental impacts from such facilities, therefore, are not well understood but should be similar to those associated with the use of other fossil fuel sources. Pollution control technologies and mitigation measures that have been or are being developed for coal combustion and gasification should be transferable with some modifications for peat technologies.

Development of peat resources for energy can probably be accomplished in an environmentally acceptable manner, but detailed environmental planning at a regional scale will be required.

29. Sheppard, J. and M.P. McKim. 1982. Investigation of the application of wet oxidation technology to the dewatering and combustion of peat. Final Report P-3543/G-7. Canada Energy, Mines and Resources, Canmet Energy Research Laboratories Contract No. DSS 18SQ.23440-0-9081.

Batch autoclave and continuous flow pilot plant experiments identified the autothermal partial oxidation reactor conditions which result in a mechanically dewaterable (up to 50% moisture) peat solid mass.

The solubilized peat mass present in the wastewaters is treatable in an anaerobic filter type reactor, resulting in further energy recovery in the form of digester gas containing up to 75% methane.

Final treatment of the digester effluents was found to be practicable in an extended aeration type of activated sludge system. Full nitrification and BOD_5 removal to < 50 mg/L effluent concentration was found to be achievable.

30. Smith, R.T. 1981. Environmental aspects of alternative wet technologies for producing energy/fuel from peat. Report 1981 DOE/FC/10169-T1, 142 p.

Peat in situ contains up to 90% moisture with about 50% of this moisture trapped as a colloidal gel. This colloidal moisture cannot be removed by conventional dewatering (filter presses, etc.) and must be removed by the thermal drying, solvent extraction or solar drying before peat can be utilized as a fuel feedstock for direct combustion or gasification. To circumvent the drying problem, alternative technologies such as wet oxidation, wet carbonization and biogasification are possible for producing energy or enhanced fuel from peat. This report describes these three alternative technologies, calculates material balances for the given raw peat feed rates of 1000 tons/hr, and evaluates the environmental consequences of all process effluent discharges. Wastewater discharges represent the most significant effluent due to the relatively large

quantities of water removed during processing. Treated process water returned to the harvest bog may force in-situ acidic bog water into receiving streams, disrupting local aquatic ecosystems.

31. Sorge, J.M., and J.S. Huston. 1981. Environmental trade-offs for large-scale peat development. In: Peat as an energy alternative II. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. 1-3 December 1981. p. 717-726.

    The ever tightening regulatory framework imposed on U.S. industry has once again altered facility siting and design procedures. Regulatory programs for air and water are familiar to industry; however, the implications of RCRA and TOSCA have not been fully integrated into the plant design function. Historically, a facility planner could utilize advances in pollution control technology to effectively convert a potential air problem to a solid waste problem. However, with the advent of RCRA, this approach may not prove advantageous since it results in a far greater waste disposal problem . The result -- industry must once again develop the methodology necessary to evaluate environmental trade-offs at the design stage in order to minimize costs, construction schedule and licensing difficulties.

    This regulatory dilemma has important implications for the embryonic peat industry in the United States. Peat deposits in the U.S. are generally associated with complex hydrologic systems located in pristine rural environments. Given these conditions, the stage is set for direct confrontation between air and water licensing specialists. The major areas of potential conflict will be identified along with a preliminary approach designed to incorporate alternative environmental scenarios and basic process design considerations.

32. Suoninen, A. 1982. Peat production. In: Peatlands and their utilization in Finland. Edited by J. Laine, Finnish Peat Society, Finnish National Committee of the International Peat Society. Helsinki, 1982. p. 67-83.

    Production of fuel peat in Finland got underway after World War II. The level of production has fluctuated with the availability of other fuel imports, but now it has regained its importance. Central and northern

Finland are the areas where most fuel peat is consumed. In 1981, 6 million m^3 of milled peat and 0.7 million m^3 of sod peat were consumed. Horticultural peat production is concentrated in southern and western Finland. Loose peat is the most common form for domestic horticultural peat, compressed peat is the most common export.

There are several steps involved in setting up a peat site. First the peatland has to be surveyed to ensure the quantity and quality of peat. It has to be drained and cleaned. Certain measures must be taken to prevent fire and to protect receiving waters.

33. Tibbetts, T.E., and A. Ismail. 1980. On the feasibility of mining peat for power generation in Canada. Canadian Mining and Metallurgical Bull. 6 p.

The paper takes its material from the peat mining and power project feasibility studies sponsored by CANMET and conducted by Montreal Engineering Company, Ltd. in the years 1976 to 1980. The role which peat may play in the Canadian energy prospectus is outlined, estimated and measured fuel peat resources are tabulated, and the economic and technical feasibility of mining peat for power generation is reviewed.

34. Tsaros, C.L. 1981. Peat dewatering, an overview. In: Conference on peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1, 1981. p. 199-216.

In order to effectively use peat, which contains 9 lb or more of water per lb of dry peat, most of the water must be removed without the use of fossil energy. Although most of the peat used today is air-dried, using solar energy, supplying the large amounts of energy needed for a typical substitute natural gas (SNG) plant by such methods could require setting aside an area of over 200 square miles for 20 years.

For peat as received from the bog, a combination of pressing and drying appears to be a feasible way to reduce the water content to below 50%. Many forms of mechanical dewatering have been used: roll and belt presses, filter presses, screw presses, centrifuges, and screens. High pressure is required to reduce the water to the 70% level. An optimum combination of high capacity and pressure is needed.

Mechanical dewatering to 70% moisture will remove most of the water in the peat. Thermal drying, with peat fuel, can be used to reduce moisture to below 50%. Use of: 1) rotary drum, 2) fluidized bed, or 3) flash dryers, all commercially available, is possible.

Other methods applicable to peat drying are the Carver-Greenfield process and solvent dewatering. The former is basically a multiple-effect evaporation process using the fluidized-bed technique. The latter is based on the principle that in certain solvents the solubility of water changes substantially with change in temperature. Wet peat is contacted with solvent at the higher temperature, dissolving water. The solvent and peat are separated, and the solvent is cooled, so that it separates into two layers - one water-rich and one solvent-rich. Solvent is recovered from the former and recycled to be mixed with fresh peat.

Wet carbonization, a beneficiation process, improves the dewaterability of peat. When wet peat is heated under pressure, e.g., 500 psig at 400°F, decarboxylation and dehydration occur, resulting in a rise of unit heating value, with consumption of peat of the total fuel value and production of gases and water-soluble organic chemicals. The product is mechanically dewatered to about 35% moisture.

There is little published information on the economics of peat dewatering. The U.S. Bureau of Mines as well as Ahlstrom (of Finland) have estimated the cost of dewatering by pressing and drying to be 50 to 60 cents/10^6 Btu.

IGT has made a preliminary comparison of four different systems for dewatering peat from 92% to 35% moisture for capacity of 33,000 tons/day of dewatered peat. The systems involve pressing to 70% moisture followed by drying to 35%. Costs average about $1 per 10^6 Btu. The most attractive method uses the Carver-Greenfield process for the drying step.

35. Yanushevskii, V.V., and Zinina, N.V. 1980. Characteristics of wastewaters of peat. Torf. Prom'st. 4: 28-30.

Wastewaters from two peat briquetting plants contained <11.685 mg/L suspended solids which could be removed by sedimentation. Sedimentation for 1.5 hours removed

85.91% of solids, while 24 hour sedimentation gave 99% solids removal. The COD of these wastewaters was 291.00 mg/L from one plant and 443 mg/L from another. The wastewaters purified by sedimentation could be recycled to briquetting, but biological treatment was required before they could be discharged.

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POOR

QUALITY

ORIGINAL